Silvicultural Benefits From Brush

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TRADITIONALLY foresters look at brush as something that must be eradicated. Large sums of money are invested annually on brush control research and on brush eradication for site preparation. Serious consideration is also being given to the control of brush to improve the growth rate of desired crop trees. This approach has resulted from our primary concern for the crop tree with little or no thought given to the ecosystem of which it is a part. Lutz (*14*) has emphasized the importance of giving adequate consideration to all components of the forest ecosystem. He has pointed up the delicate equilibrium existing in the single crop system. He states "that the more nearly natural and the more complex the forest ecosystem the less likely will be violent fluctuations in the physical environment and in the plant and animal components." As foresters we are woefully ignorant of the complex system for which we are responsible. We have been concerned primarily with how fast a tree grows, how much it produces, some of the gross factors influencing growth, and how to harvest it. We have given little or no consideration to the complex interactions at work in the forest. Research in progress now is beginning to elucidate some of these relationships but there is a long way to go. As Orr (15) has so aptly put it, "As one broadens the area of knowledge, he lengthens the perimeter of ignorance."

The role that brush and so-called "weed species" play in the forest ecosystem is a good case in point. Voluminous amounts of evidence have been accumulated concerning the detrimental influence of brush and the benefits derived from eradicating it. Much effort has gone into developing methods of eradication. On the other hand little or no thought has been given to some of the side effects of these operations. In addition, very little consideration has been given to some of the beneficial influences of brush and "weed species." There is ample evidence, in our present state of knowledge, that complete eradication of brush is necessary to assure success of some reforestation projects. However, this knowledge does not relieve us from the responsibility of learning more about how these operations influence the ecosystem, especially the soil, or from developing less drastic management techniques. Also it does not permit us to make the broad generalizations we are so prone to make. It should serve to stimulate efforts in obtaining a more complete understanding for the forest ecosystem. It is with one small facet of this that this paper is concerned, i.e., the beneficial role of brush.

Much has been said concerning the soil building or improving role of many hardwood species on deteriorated sites. The nitrogen fixing capacity of black locust and other legumes has also been given considerable attention. Recently interest has been increasing in the nitrogen fixing capacities of non-leguminous species, including both trees and brush. However, very little has been written concerning other beneficial influences. Occasionally some "voice in the wilderness" has been heard but usually ignored and soon forgotten. In 1924, Show (*17*) working with ponderosa pine in California found that brush cover increased seedling survival. However, he noted that quality of planting improved as brush cover decreased. Wahlenberg (*25*) in western Montana found more favorable moisture and temperature relations under *Ceanothus* brush than in open areas. He also noted greater survival and a more thrifty condition of ponderosa pine seedlings planted under the brush than in the open. It is highly probable that in both areas more effort is going into brush eradication than into training planting crews to take advantage of these benefits. Although more is being learned about the nitrogen fixation activities of many non-leguminous woody plants in the forest ecosystem, we are still busily engaged in eradicating them.

There is also evidence accumulating concerning the decline of forest stands due to changes in microbiological activities in the soil and the role that brush and "weed species" play in revitalizing the site (11). The biological activities taking place in the soil, including nitrogen fixation, organic matter decomposition, humus formation, production of growth regulating substances and other root-soil relationships can be of great significance in influencing the growth and health of the forest. Changes or treatments made in the forest may readily be seen in marked changes in soil moisture and temperature regimes. Not as easily seen, but often times more profound and long lasting are changes in the biological activities in the soil.

Brush and Ponderosa Pine Reproduction

Soil moisture and temperature.—In 1954 the Oregon Forest Research Laboratory established direct seeding studies in four cutover areas in the ponderosa pine zone of central Oregon (*23*). The soils are coarse gravelly sands developing in pumice from Mt. Mazama and Newberry crater (27). The residual stands consisted of scattered ponderosa pine (*Pinus ponderosa* Laws.) with some western juniper (*Juniperus occidentalis* Hook.), lodgepole pine (*Pinus contorta* Dougl.) and white fir (*Abies concolor* Lindl. and Gord.). Brush species included snowbrush (*Ceanothus velutinus* Dougl.), manzanita (*Arctostaphylos parryana* Lemmon var. *pinetorum* [Rollins] Wieslander and Schreiber), bitterbrush (*Purshia tridentata* DC.), currant (*Ribes cereum* Dougl.), rabbit-brush (*Chrysothamnus nauseosus* [Pall] Britt.), and sagebrush (*Artemisia tridentata* Nutt.). Idaho fescue (*Festuca idahoensis* Elm.) and squirrel-tail (*Sitanion hystrix* [Nutt.] J. G. Sm.) are the dominant grasses. Other herbaceous vegetation is very sparse. Annual precipitation in the four areas is 20 inches or less, most of it occurring in the dormant season. Of some concern to the project leader was the competitive influence of grass and the various shrubs for soil moisture.

Accordingly a cooperative study of soil moisture and temperature was initiated in 1955. Stacks of Colman fibreglass units were installed in the fall of 1955 and readings taken at weekly intervals during the 1956-1959 seasons. Three stacks of units were installed in open bare ground situations, under grass and under the various shrub species. In one area a mulch of pine needles was also included in the open condition.

Although the study was designed to evaluate the competitive effects of vegetation it soon became evident that the brush cover was exerting a beneficial effect both with respect to moisture and temperature relations. The dates at which soil moisture reached the permanent wilting point in the seedling root zone are presented in Table 1. It is apparent that grass is the only serious competitor for soil moisture in these areas. In all cases moisture was available for longer pe-

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Table 1.—Date at Which Soil Moisture Reached Permanent Wilting Point in the Seedling Root Zone (0-6") Under Different Cover Types in Central Oregon

Cover	Date PWP reached			
	1956	1957	1958	1959
	Kiwa Springs			
Open	8/26	8/15	8/12	7/25
Grass (Idaho fescue)	7/31	7/20	8/10	7/10
Manzanita	10/5	-------	-------	-------
Snowbrush	-------	-------	-------	-------
	Tumalo Reservoir			
Open	7/21	7/1	8/1	7/10
Open & mulch	8/10	8/5	8/15	7/15
Grass (Idaho fescue)	7/29	7/5	8/15	7/15
Rabbitbrush	9/1	8/10	-------	7/25
Bitterbrush	10/2	8/25	-------	7/25
	Summit Stage			
Open	8/29	8/10	8/15	8/1
Grass (Squirreltail)	8/6	8/5	8/10	7/10
Bitterbrush	-------	8/25	-------	8/15
	Sand Springs			
Open	8/25	7/20	10/10	7/15
Grass (Squirreltail)	7/14	7/5	8/10	7/1
Sagebrush	9/2	8/25	-------	8/1
Currant	9/10	8/20	-------	8/5
Bitterbrush	9/1	8/25	-------	7/25

Table 2.—Maximum Soil Temperature Recorded at 2-Inches Below Surface Under Different Cover Types in Central Oregon

Cover	Temperature (°F)			
	1956	1957	1958	1959
	Kiwa Springs			
Open	82	77	80	83
Grass (Idaho fescue)	69	68	80	72
Manzanita	55	56	60	58
Snowbrush	56	52	61	62
	Tumalo Reservoir			
Open	96	87	80	93
Open & mulch	81	81	76	86
Grass (Idaho fescue)	78	72	73	74
Rabbitbrush	72	70	67	67
Bitterbrush	64	64	64	71
	Summit Stage			
Open	81	76	76	85
Grass (Squirreltail)	73	72	75	85
Bitterbrush	60	56	55	64
	Sand Springs			
Open	70	67	63[1]	90
Grass (Squirreltail)	61	66	60	88
Sagebrush	54	51	50	65
Currant	52	52	56	64
Bitterbrush	52	50	58	65

[1]1958 temperature readings at Sand Springs were made in the early morning.

Table 3.—Levels of Nutrients in the Seedling Root Zone in a Pumice Soil Under Snowbrush, Manzanita, and Bare Ground Conditions

	Total N	Avail. P	Exch. K	Exch. Ca
	Percent	*ppm*	*me/100g*	*me/100g*
		Litter		
Open	0.58	47	2.4	11.4
Snowbrush	1.20	45	2.3	32.1
Manzanita	0.72	64	2.8	21.2
		A_1 horizon		
Open	0.11	16	0.5	3.7
Snowbrush	0.16	22	0.9	8.0
Manzanita	0.12	27	0.9	4.9
		Ac horizon		
Open	0.05	10	0.4	2.3
Snowbrush	0.07	10	0.7	4.2
Manzanita	0.05	10	0.7	2.5

riods of time under brush cover than in the open (bare ground) or under grass. In the Kiwa Springs area moisture depletion never became a critical factor under manzanita or snowbrush. An examination of the root systems of these two plants revealed that most of the fine roots extended out into the open areas with very few occurring directly under the brush crown. To a lesser degree this same phenomenon was true for the other species in the area.

Competition for soil moisture under brush becomes more critical at depths of 18 and 24 inches. Barrett and Youngberg (*2*) have shown that the removal of snowbrush and manzanita in a sapling stand of ponderosa pine decreases the consumptive use of moisture by the stand and increases diameter growth. However, during the period of initial seedling establishment moisture conditions in the root zone are most favorable under brush. This suggests that after seedling establishment a release operation may be beneficial. It is not known what the long term effects of spraying snowbrush and manzanita will have on the growth of the stand. It is entirely possible that the loss of nitrogen fixation by snowbrush may cancel out the initial benefits of its removal.

The maximum temperatures recorded at 2 inches below the surface under the different cover types are given in Table 2. Temperatures at the surface in the open at these same times ranged from 145-165°F. Temperatures under brush cover were generally 20 to 30 degrees cooler than in the open. At Tumalo Reservoir pine needle mulch had some ameliorating effect in lowering soil temperatures. However, grass was more effective in this respect than mulch. The ameliorating effect of grass is negated by its moisture competition.

It appears, then, that soil moisture and temperature conditions are most favorable for seedling survival and establishment under brush cover and least favorable under grass and open bare ground. These findings are in agreement with those of Dyrness[1] working in virgin ponderosa pine stands on similar soils. He found that from 60 to 85 percent of the seedlings and saplings in these stands occurred under the cover of snowbrush, manzanita and bitterbrush. He also observed that moisture depletion to the permanent wilting point was 1 to 3 weeks later under brush than in the open.

Soil fertility.—Brush can and does play an important role in influencing soil fertility. In a system where much of the nutrient capital is concentrated in the organic layers the accumulation of litter under brush significantly influences the fertility in the seedling root zone. In forest ecosystems where symbiotic nitrogen fixing plants occur,

[1]C. T. Dyrness. Soil-vegetation relationships within the ponderosa pine type in the central Oregon pumice region. Unpub. Ph.D. thesis, Oregon State Univ., Corvallis 1960.

the influence can be even more important. The data in Table 3 demonstrate both of these relationships. Nutrient levels are higher under snowbrush and manzanita than in the open. The accumulation of more nitrogen under snowbrush is related to symbiotic nitrogen fixation to be discussed in more detail later. It will suffice to say here that the higher nitrogen and calcium content under snowbrush create very favorable conditions for seedling growth. This is reflected in the thrifty condition of ponderosa pine seedlings growing in snowbrush clumps. These same relationships have been observed with other species of *Ceanothus* and tree seedlings.

Mechanical protection.—One other benefit derived from the presence of brush is the protection it offers reproduction from grazing livestock and larger wildlife. It is not at all uncommon to observe reproduction in open areas that has been browsed by sheep, cattle or deer while that in the brush remains unbrowsed. This is another factor that should be taken into consideration in the timing of brush spraying as a release operation.

Symbiotic Nitrogen Fixation

The role of legumes in increasing soil nitrogen has long been recognized and widely used in agricultural practices. A number of workers have discussed the use of legume species for improving soil nitrogen levels on forest sites (*1, 6*). Of greater significance in this respect is the presence of numerous nodulated non-leguminous plants in forest ecosystems. Many of these plants have been shown to be involved in nitrogen fixation in symbiotic relationships similar to those occurring in legumes. In 1963 Bond (*5*) listed the genera known to have species with root nodules. His summary is presented in Table 4. Since then three additional genera, *Purshia, Cercocarpus* and *Podocarpus* have also been found to have nodulated species (*2, 22, 24*). These are also listed in Table 4. At the present time there are 13 genera with 278 species, many of which have been found to be nodulated. Included in eight of these genera are many nodulated species that occur in North American forests.

Table 4.—Non-Legume Nodule Bearing Genera

Genus	No. of species	Present in North America
Coriaria	10	
Myrica	44	X
Comptonia	1	X
Alnus	25	X
Casuarina	35	
Elaeagnus	30	X
Shepherdia	3	X
Hippophaë	2	
Ceanothus	40	X
Discaria	15	
Purshia	2	X
Cercocarpus	6	X
Podocarpus	65	

Bond (*4*) has demonstrated that many of the non-leguminous nodulated plants are as efficient nitrogen fixers as the legumes. Most of the work done to date with these species has been in the laboratory and greenhouse. There is, however, much indirect evidence indicating their importance in soil nitrogen enrichment. Crocker and Major (*7*) have shown the importance of alder in increasing soil nitrogen in fresh glacial deposits in Alaska. Dyrness and Youngberg (*9*) found greater accumulation of nitrogen in pumice soils where *Ceanothus* was a large component of the understory vegetation than where it was absent or present in only small amounts. Tarrant and Miller (*19*) observed that 938 pounds more nitrogen per acre accumulated over a 26-year period in a mixed stand of red alder (*Alnus rubra* Bong) and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) than in a pure Douglas-fir stand. Tarrant (*18*) reported significant increases in height and diameter growth of Douglas-fir in the mixed stand as compared to the pure stand. Dale (*8*) reported that alder increased the height growth of pines and other hardwood species in strip-mine plantings. Growth of one species was increased 53 percent over a five year period. Lowry, et al., (*13*) have also recommended the use of alder for soil improvement in Ohio strip-mines.

Wax myrtle (*Myrica cerifera* L.) and bayberry (*M. carolinensis* Mill.) occur commonly in forests on sandy soils in eastern North American and sweetfern (*Comptonia peregrina* [L.] Coult.) occurs commonly on sandy soils in northeastern United States and eastern Canada. It is especially common on so-called barrens that have been severely burned. *Shepherdia* and *Elaeagnus* are widespread throughout northern U. S. and Canada and in the Rocky Mountains. Little or no work has been done in the field with these plants but they have been shown to be involved in nitrogen fixation in laboratory studies (*4*).

Ceanothus is one of the most widespread nodulated non-leguminous genera in the United States. Two species occur in central and eastern United States and the remainder occur in the western part. Many of these species occur in forest ecosystems. Most of the work done thus far on *Ceanothus* has been in the laboratory (*11, 16, 21, 26*). In a pot study Wollum and Youngberg (*26*) have shown that nitrogen fixation was equivalent to 70 pounds per acre for a one-year period. Evans[2] has grown nodulated snowbrush seedlings in nitrogen-free media and recorded gains of 290 milligrams of nitrogen in a 20-week period. Veirs[3] has observed that *Ceanothus velutinus* improves the growth of Douglas-fir in northern California. Wollum and Youngberg (*26*) have also found that ponderosa pine seedlings and saplings growing in clumps of snowbrush have a higher foliar nitrogen content than similar plants growing in the open. Associated with the higher nitrogen content is greater needle length and total mass of foliage. It is apparent from these observations plus those of others (*5, 9, 12, 15, 21*) that the genus *Ceanothus* has a significant influence on nitrogen nutrition in forest ecosystems.

Observations made in the ericaceous barrens of western Nova Scotia reveal a beneficial role for sweet fern in relation with white pine (*Pinus strobus* L.) and red spruce (*Picea rubra* Link) seedlings. In planting pine and spruce seedlings the ericaceous vegetation and thick raw humus layers are often scalped before planting. The seedlings are then planted in the leached A_2 horizon and by the end of the first growing season are often very chlorotic. On the other hand where the seedlings are growing in close association with sweet fern they have a healthy green appearance and are making vigorous growth.

Following the deposition of fresh glacial material from the Kantz Creek glacier in Mt. Rainier National Park true fir (*Abies* spp.) seedlings growing in close association with red alder seedlings made much more vigorous growth and were healthier looking than seedlings not growing in association with alder.

Nitrogen fixation involving symbiosis between several non-leguminous genera and various microorganisms is a common phenomenon in many forest ecosystems. This relationship has been observed to be beneficial to a number of tree species and in various stages of their development. However, more research is needed to evaluate the long-term effects of this nitrogen fixation in forest ecosystems. With this in mind three permanent study plots have been installed in western and central Oregon to evaluate nitrogen fixation by *Ceanothus* and its influence on the growth of Douglas-fir and ponderosa pine.

Rhizosphere Relationships

In relating forest growth to soil conditions most of the emphasis has been placed upon physical factors, those soil factors that influence moisture re-

[2]H. J. Evans, personal communication.
[3]E. I. Veirs, personal communication.

Table 5.—Mineralization of Nitrogen as Measured by Uptake by Two Crops of Douglas-Fir Seedlings

Litter type	Nitrogen uptake pct. of added N
Salal	2.2
Sword fern	4.7
Vine maple-salal	6.0
Salal-swordfern	8.1
Vine maple-swordfern	9.9

lations and aeration. The reason for this emphasis is that physical factors can be evaluated in the field and also related to soil survey information. In recent years the increase in fertilizer research has resulted in more emphasis being placed on the influence of fertility on tree growth. Very little attention has been given to soil microbiology and rhizosphere relationships and their influence on tree growth with the exception of studies on soil borne diseases, mycorrhizal relations, and nitrogen fixation. However, literally speaking there is more activity in the soil than meets the eye.

The influences of soil microbiological processes on forest growth are very difficult to evaluate, but there are strong suggestions that they can be very important. The decline of some old-growth redwood stands has been shown to be related to changes in the population of soil organisms that allow buildups of soil borne diseases (*11*). It is sugested that the development of brush and hardwood weed species following logging in these stands has an ameliorating effect on this condition.

Some tree species appear to be self-destructive due to the influence of their litter on the microbial populations in the soil (*10*). The presence of other species in the system is necessary to alleviate these conditions. Recent studies have shown that there are numerous antagonisms occurring in the soil which may have profound influence on forest stands (*20*). The presence of certain species, including species of lesser vegetation, can have a profound effect on the microbiological processes taking place in the soil. The importance of this to tree growth can be demonstrated in the rate at which nitrogen is released from different types of forest litter.

The mineralization or release of nitrogen from various kinds of forest litters is shown in Table 5. All five types were mixtures of Douglas-fir litter and the litter of understory species.[4] In the salal (*Gaultheria shallon* Pursh.) and sword fern (*Polystichum munitum* Kaulf. Presl.) litter types these two species are the dominant understory plants. Small amounts of other plants are also present. It can be seen that mixture of salal or swordfern litter with the litter of other species results in greater mineralization of nitrogen than where the litter of these two species is the major component. This is a result of greater microbiological activity and more rapid decomposition with greater diversity of organic material. In addition to more rapid mineralization of nitrogen other nutrient elements are also released more rapidly.

In nitrogen fixation studies with *Ceanothus* it has been observed that nodulation of *Ceanothus* seedlings is much more rapid following clearcut and slash burning in younger Douglas-fir (100-120 years old) stands than in older stands (300-400 years old). The population of *Streptomyces,* a species of which causes nodulation, is much higher in the soil and rhizosphere in the younger stands than in the old growth areas. The cause for these differences is not understood; however they point up the delicate balance that exists in the soil. It is evident that in one situation *Ceanothus* is serving as a nurse crop for seedlings by ameliorating soil moisture and temperature conditions and also increasing soil nitrogen. In the second situation the benefits from enrichment in soil nitrogen is either non-existent or slower in coming.

Summary

Many complex interactions are taking place in forest ecosystems between crop trees, associated vegetation, including weed species and brush, and microorganisms in the soil. In most situations where brush and weed species are being eradicated little or no thought is being given to the possible side effects of this practice or to the loss of beneficial effects exerted by many of the species being eradicated. A more thorough understanding is needed of the roles, both beneficial and detrimental, played by these species in the development of a healthy forest. Much additional research is needed to give us a better understanding of the complex system with which we are dealing. Until we have this understanding we will continue to tread on thin ice in many of our stand manipulations.

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[4]The details of this study will be published in *Soil Sci. Soc. Amer. Proceedings.*

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